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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

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TESTS OF A $\frac{1}{17}$-SCALE MODEL OF THE XBDR-1 AIRPLANE IN THE NACA GUST TUNNEL

By Thomas D. Reisert

SUMMARY

Tests were made in the gust tunnel on a $\frac{1}{17}$-scale model of the XBDR-1 airplane to verify the calculated effective gust factor. Tests were made for three gust shapes, one forward velocity, and one wing loading.

Theoretical calculations and results of experiments are in agreement for the airplane with a center of gravity at 20 percent mean aerodynamic chord. For aft center-of-gravity positions, the results of an analysis indicate that the effective gust factor is appreciably higher. From the results of the analysis it is recommended that a value of 1.22 be used as the effective gust factor in the design of the XBDR-1 airplane.

INTRODUCTION

In response to a request for information on the effective gust factors for the XBDR-1 airplane by the Bureau of Aeronautics, Navy Department, it was recommended and subsequently approved that tests of a scale model be made in the gust tunnel. Study of the airplane had indicated that one of the important variables governing the gust load factor would be the stability of the airplane. A secondary factor would be the influence of various rates of development of lift along the span on the wing bending moments in gusts. In view of the unconventional character of the airplane involved, it was felt that any analytical work should be verified by experiment.

This report presents the results of gust-tunnel tests on a $\frac{1}{17}$-scale model of the XBDR-1 with power off and also the results of an analysis made to determine the effective gust factor. The tests were made during October 1943 in the gust tunnel at Langley Field, Va.

APPARATUS

The gust tunnel and auxiliary equipment have been described in reference 1.

The $\frac{1}{17}$-scale model of the XBDR-1 airplane is shown in figure 1. Pertinent characteristics of the model as tested and of the full-scale airplane are given in table I. In addition to geometric scaling of the airplane to reproduce the aerodynamic characteristics, the weight and mass distributions were scaled as nearly as possible to obtain dynamic similarity. The data given in table I were obtained from the Interstate Aircraft and Engineering Corporation. The slope of the lift curve presented in table I was obtained from the results of force tests of the gust-tunnel model in the NACA free-flight tunnel. These results are given in figure 2.

The three gust velocity distributions for which the tests were made (gradient distance $H = 0.75$, 8.0, and 17.5 chord lengths) were approximately linear and are shown on figure 3 as plots of the ratio of local gust velocity U to the average maximum gust velocity $U_{max_{av}}$ against the distance in chord lengths from the leading edge of the gust tunnel.

TESTS

It was contemplated to fly the model with two center-of-gravity positions (24 percent and 28 percent mean aerodynamic chord) for three gust gradients. However, in preliminary tests it was found that it was impossible to trim the model for steady gliding flight with the center of gravity at 24 percent mean aerodynamic chord. Since steady gliding flight just before penetrating the gust is necessary in order to obtain data

suitable for analysis, the test program was changed so that all tests were made with the more stable center-of-gravity position of 20 percent mean aerodynamic chord. The stability of the model was increased sufficiently by this center-of-gravity transition to allow the model to be trimmed with the elevons. Force tests made in the NACA free-flight tunnel (fig. 2) showed that the neutral point was at 24 percent mean aerodynamic chord. The model was flown throughout the tests at a velocity corresponding to 182 miles per hour (full scale) with an elevon setting of 0°. This was the maximum speed possible on the gust-tunnel apparatus.

The tests consisted of flights over the gust tunnel at fixed values of forward velocity and of average maximum gust velocity. A minimum of five flights was made for each of the three gust gradients. Measurements of forward velocity, gust velocity, normal acceleration increment, and pitch-angle increment were made during each flight.

RESULTS

The records for all flights were evaluated to yield histories of the normal acceleration increment and pitch increment during the traverse of the gust. Sample results are shown in uncorrected form in figures 4, 5, and 6.

The maximum acceleration increments for each flight were corrected for minor variations in gust velocity and forward velocity to the nominal values for the model given in table I. The results are given in figure 7 plotted against the gradient distance in chord lengths.

The acceleration ratio for each flight was obtained by dividing the maximum acceleration increment by the "sharp-edged-gust" acceleration increment Δn_s (reference 2). A comparison of the experimental values with results obtained using the conventional method of reference 1 for calculation of the acceleration ratios is shown in figure 8.

The effective gust factor is taken as the ratio of the acceleration ratios of the XBDR-1 and B-247 airplanes in 8-and 9-chord-length gusts, respectively. It has been determined that this discrepancy in gust gradient

distance for all practical purposes is negligible. The effective gust factors obtained in this manner are presented in figure 9 with the design curve shown in figure 1 of reference 3 and a calculated value based on the method of reference 4.

PRECISION

The measured quantities are estimated to be accurate within the following limits for any single test or run:

Acceleration increment, g	±0.05
Forward velocity, ft/sec	±0.5
Gust velocity, ft/sec	±0.1
Pitch-angle increment, deg	±0.5

In any given flight, minor variations in the launching speed, attitude, or setting of the model introduce errors into the acceleration increment which are primarily a function of the pitching motion of the model. In most cases the tendency was to pitch upward and then level off just prior to entry into the gust. Sufficient flights were made so that only flights with steady portions were used to evaluate results. Consideration of all the factors involved indicates that the results from repeat flights should have a maximum dispersion of not more than ±0.15g for a gust with a gradient distance of 17.5 chord lengths and ±0.08g for a gust with a gradient distance of 8 chord lengths.

DISCUSSION

The results as shown in figure 9 indicate that, for the model in the stable condition as tested, the conventional theory yields substantially correct results and that the effective gust factor (alleviation factor K) of reference 3 is satisfactory for use in the design of this airplane for these conditions. As given in table I, the range of center-of-gravity positions for the full-scale airplane was farther aft. For the more aft center-of-gravity positions, adverse pitching motion due to the gust may cause an increase in the effective gust factor.

As previously mentioned, it was impractical to fly the model with farther aft center-of-gravity positions,

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Therefore, for these conditions an analysis based on reference 4, which includes the effect of pitching motion, was made to determine the effect of the center-of-gravity position on the effective gust factor. This analysis differs from reference 4 only in that the stabilizer terms were omitted.

Consideration of the XBDR-1 configuration indicated that the conventional unsteady lift curves could not be used due to the difference in the rate of development of lift at the root and tip and the gradual penetration of the complete airplane in the gust as the result of sweepback. In order to include these effects, the infinite aspect-ratio curves of Küssner and Wagner, as obtained from reference 5, were used with strip theory to obtain unsteady lift functions for the complete airplane including the variation in wing pitching moment due to the gradual penetration of a gust.

Comparison of the results of the analysis with experimental values is shown in figures 7, 8, and 9. The variation of the effective gust factor with center-of-gravity position for an 8-chord-length gust, as obtained from this analysis, is shown in figure 10. From this figure it is evident that the analysis indicates an appreciable change in effective gust factor with the center-of-gravity position.

In view of the agreement obtained with test results by the analysis for the 20-percent center-of-gravity position and lacking experimental verification for other points, it is felt that the results of the analysis shown in figure 10 should be used as a basis for design.

As previously mentioned, it was felt that the various rates of development of lift along the span might influence the wing bending moment. Therefore, a brief analysis based on strip theory was made of the effect on the bending moment of these rates of development of lift as governed by the degree of sweepback and taper existing on the XBDR-1 wing. The results of this analysis indicated that the effect was negligible.

CONCLUSIONS

The test results and analysis were in good agreement, and the results of the analysis indicated that there was

an appreciable change in effective gust factor for the center-of-gravity movement considered. For the XBDR-1 with the characteristics listed in table I, the value of the effective gust factor varies from 1.08 for the 20-percent center-of-gravity position to 1.22 for the 28-percent center-of-gravity position. It is recommended that a value of 1.22 be used for the effective gust factor in the design of the XBDR-1 airplane.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 3, 1944.

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2. Rhode, Richard V.: Gust Loads on Airplanes. SAE Jour., vol. 40, no. 3, March 1937, pp. 81-88.

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5. Jones, Robert T.: The Unsteady Lift of a Wing of Finite Aspect Ratio. NACA Rep. No. 681, 1940.

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TABLE I

CHARACTERISTICS OF AIRPLANE MODEL

	Model	XBDR-1
Weight, lb	2.2	10,800
Wing area, sq ft	1.25	362
Wing loading, lb/sq ft	1.76	29.8
Span, ft	3.04	51.66
Mean aerodynamic chord, ft	0.463	7.88
Center of gravity, percent M.A.C.	20	24 to 28
Moment of inertia mK_y^2, slug-ft^2	0.001805	2562
Slope of lift curve, per radian	3.73	3.73
Gust velocity, ft/sec	7.28	30
Forward velocity, mph	44.3	182
Mass parameter M	26.9	26.9
Δn_s, g	1.20	1.20

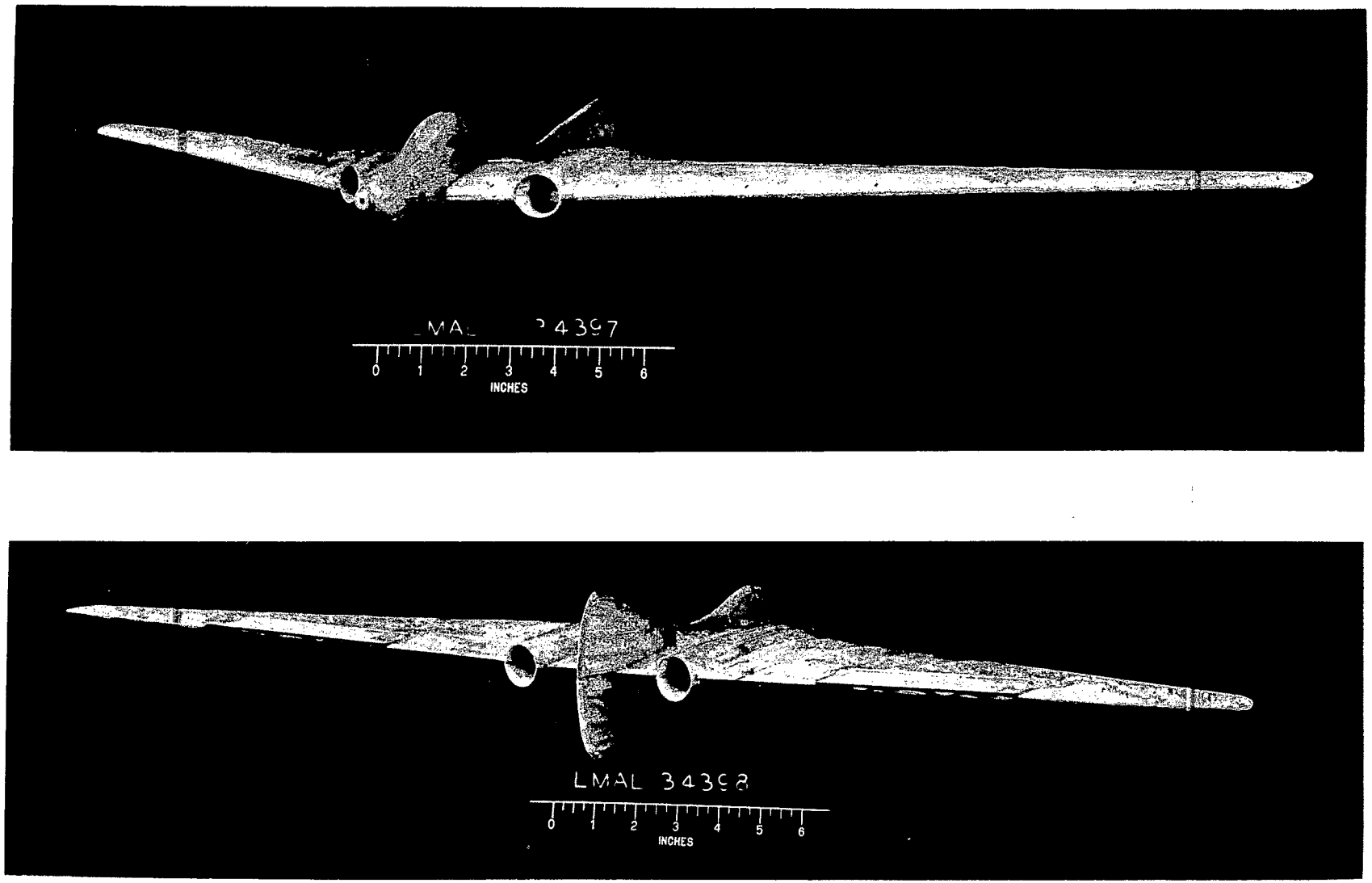

Figure 1.- Gust-tunnel model of XBDR-1 airplane.

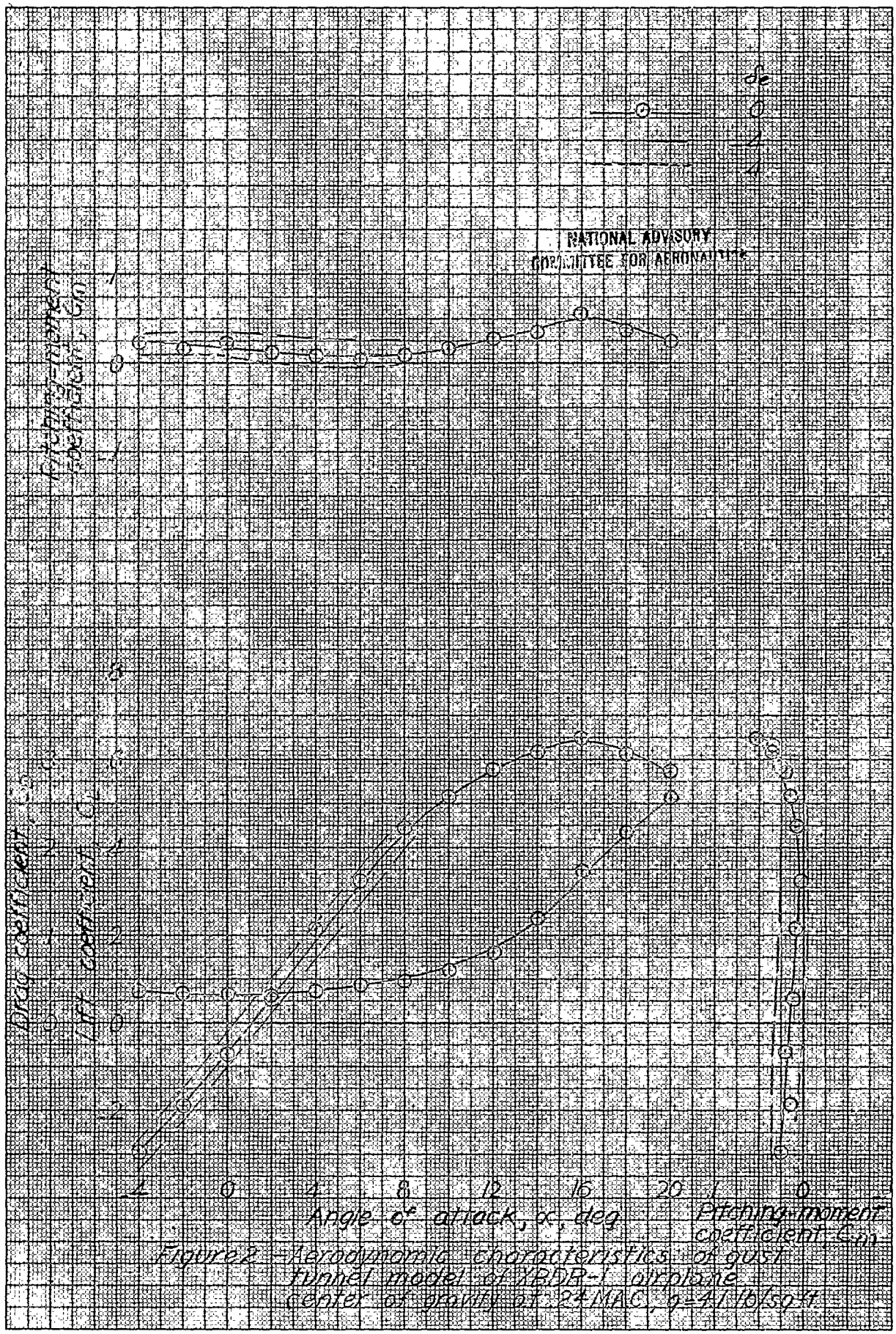

Figure 2.- Aerodynamic characteristics of wind tunnel model of XBDR-1 airplane. Center of gravity at 24% MAC; q=41 lb/sq ft.

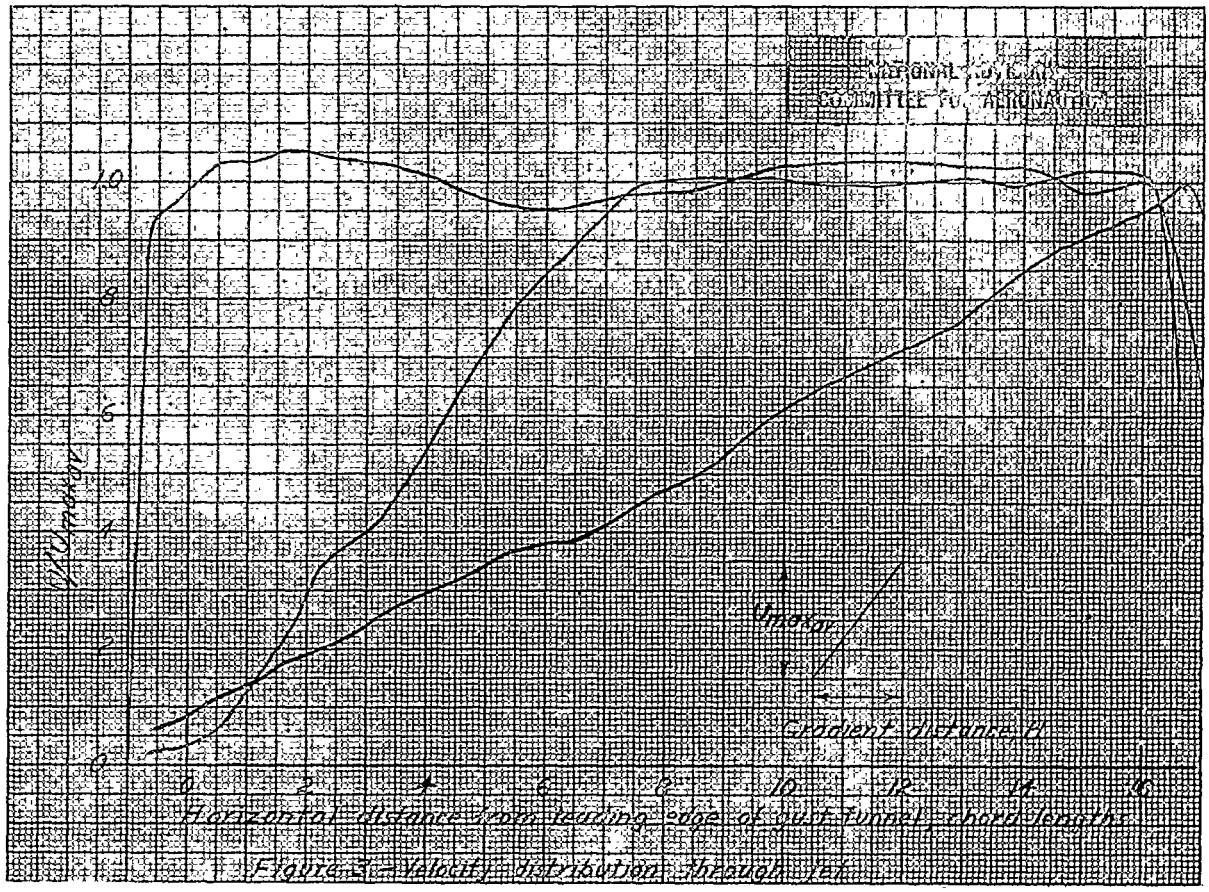

Figure 3.—Velocity distribution through jet.

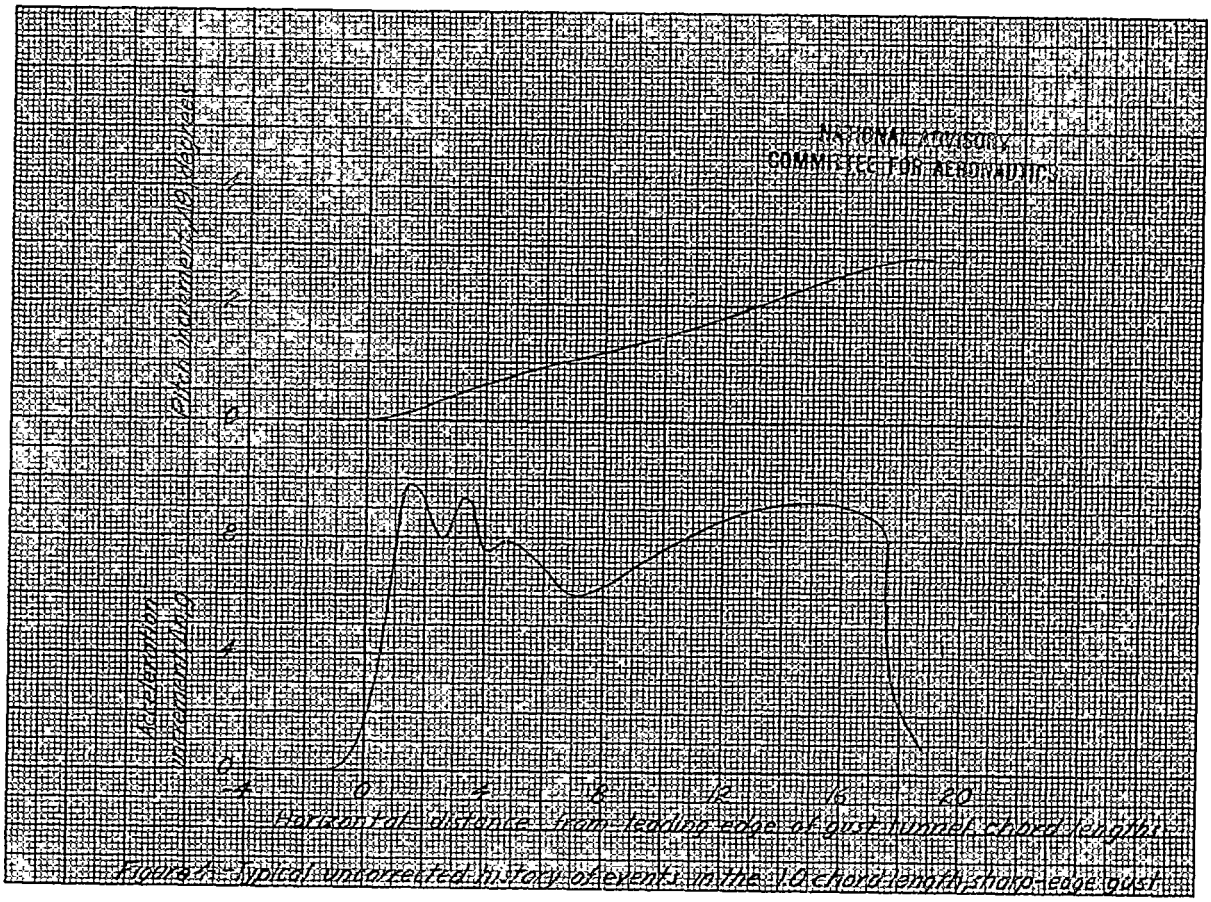

Figure 4.—Typical uncorrected history of events in the 1.0 chord-length sharp-edge gust.

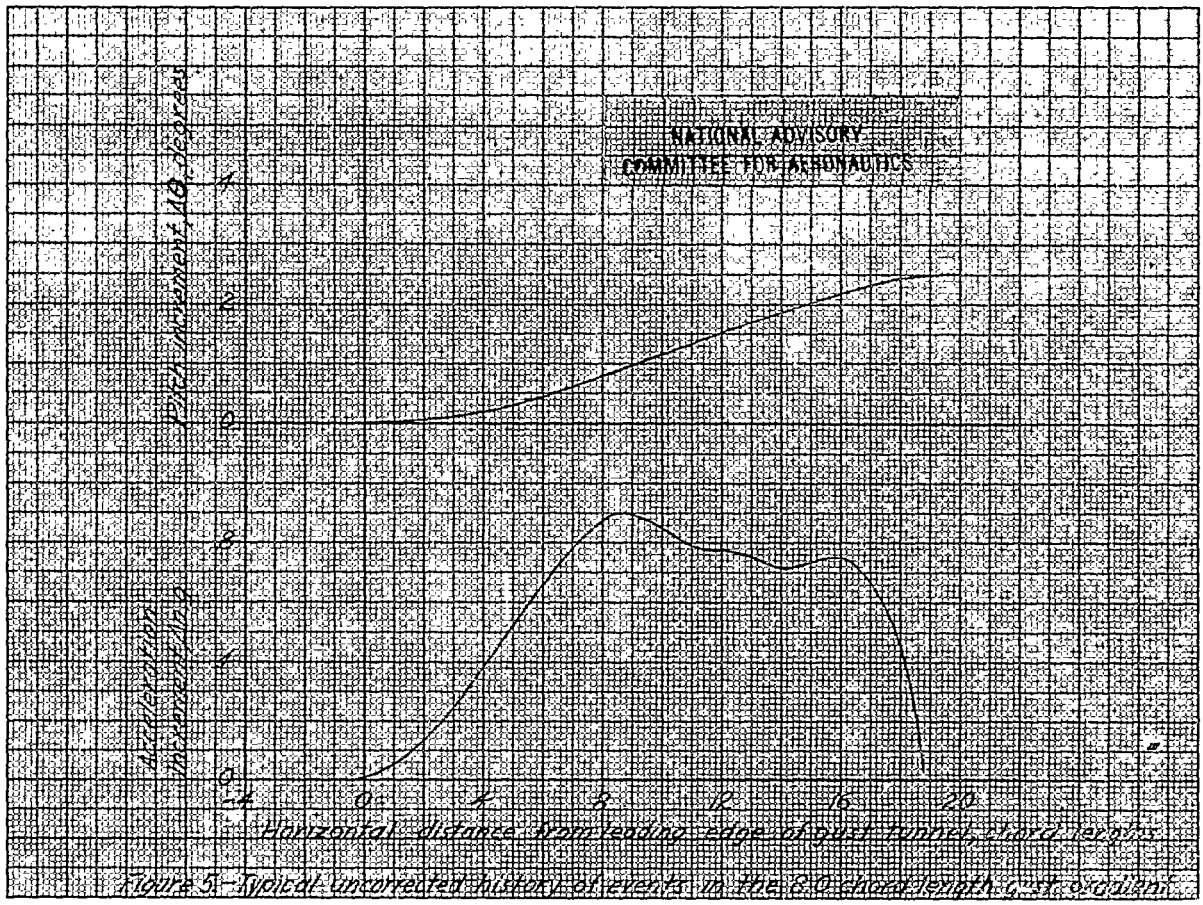

Figure 5.- Typical uncorrected history of events in the 8.0 chord length gust gradient.

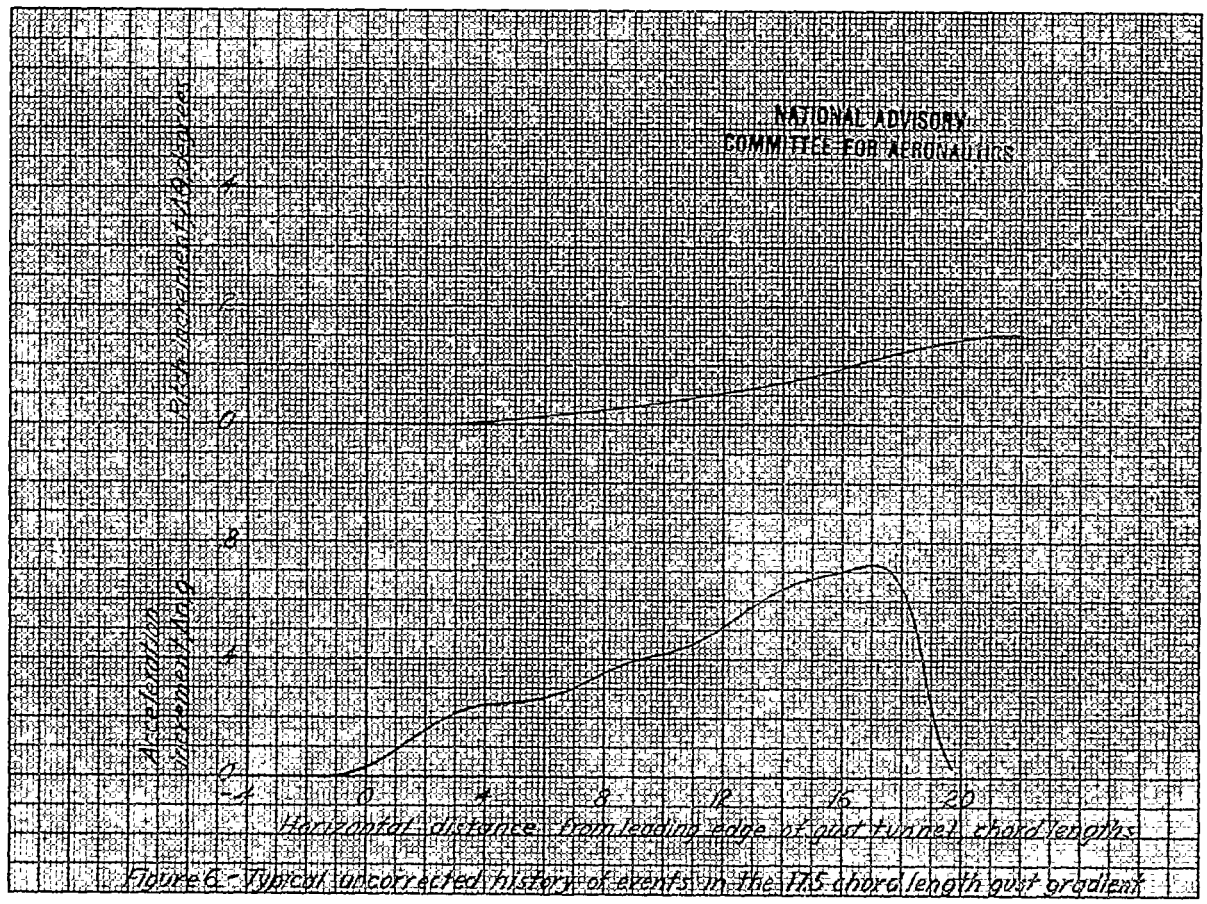

Figure 6.- Typical uncorrected history of events in the 17.5 chord length gust gradient.

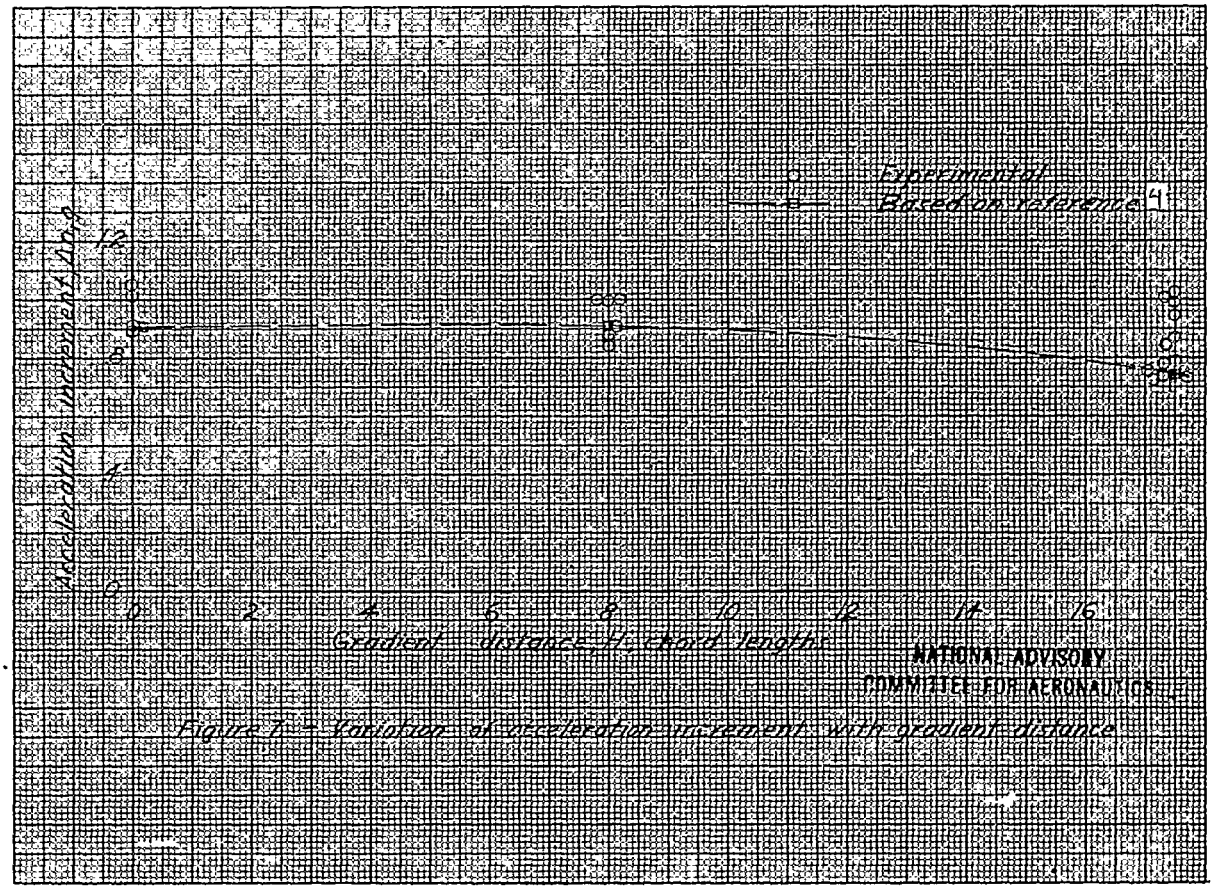

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Figure 7 - Variation of acceleration increment with gradient distance

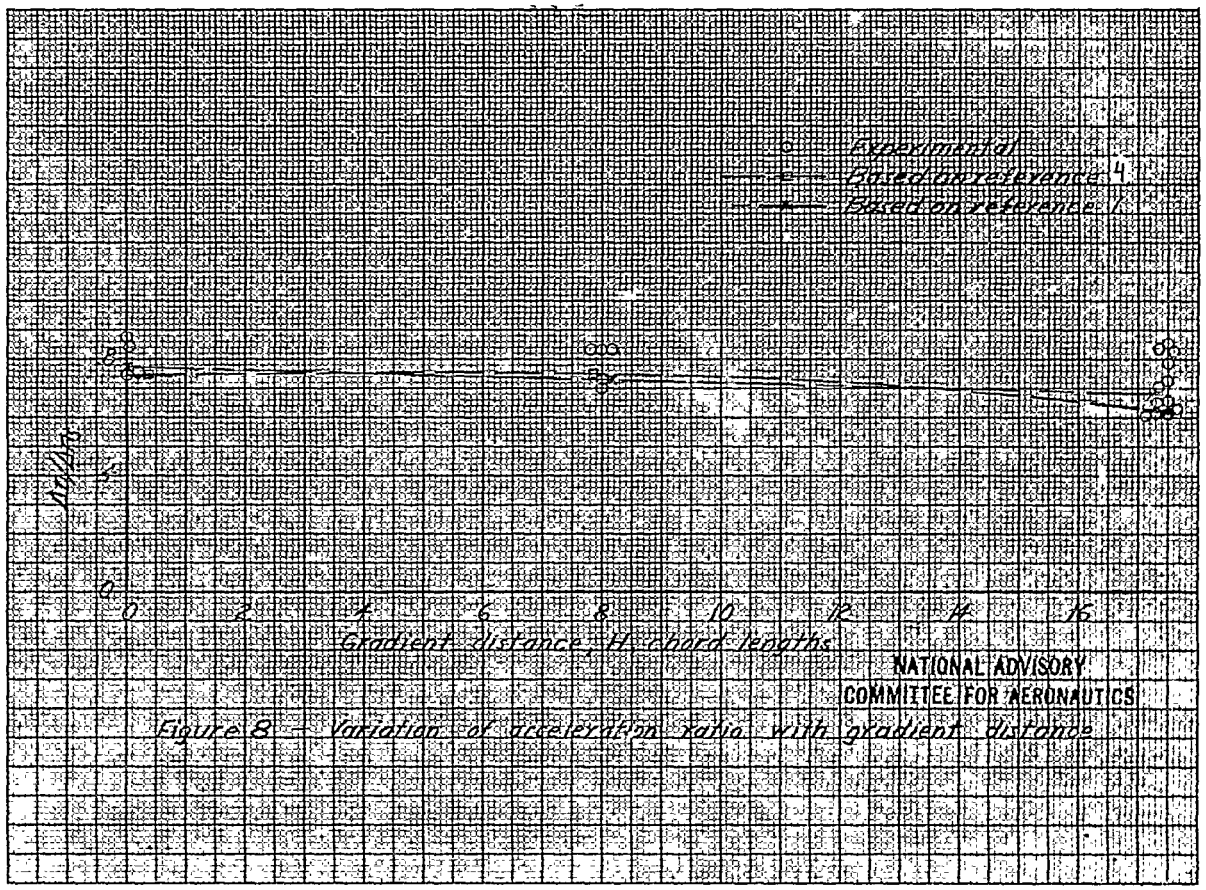

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Figure 8 - Variation of acceleration ratio with gradient distance

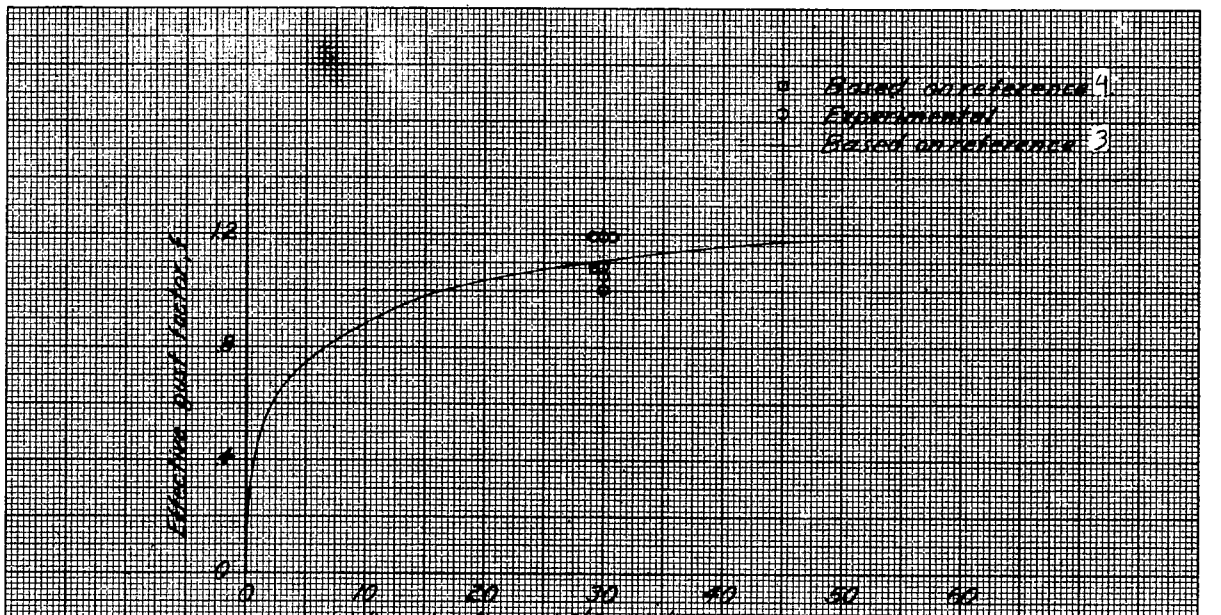

Figure 9. Variation of effective gust factor with wing loading.

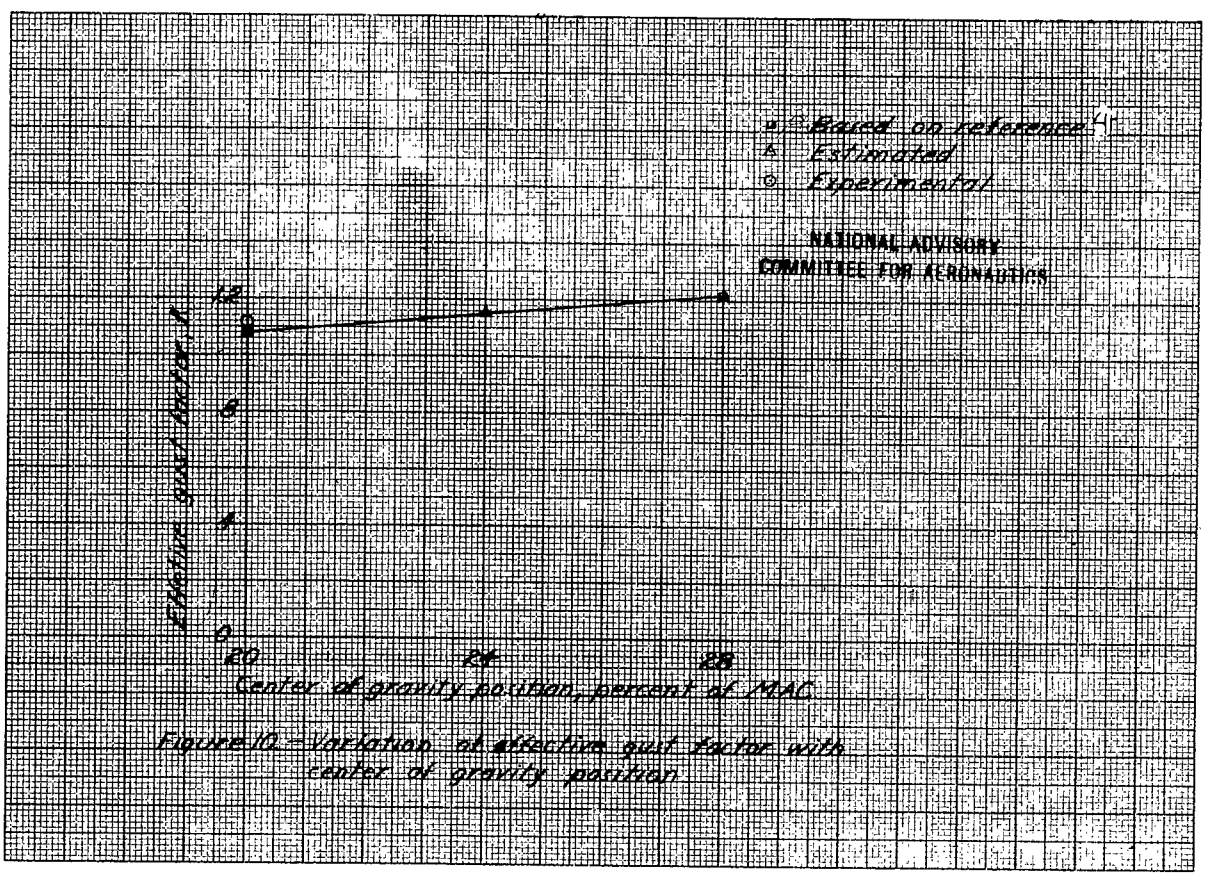

Figure 10.- Variation of effective gust factor with center of gravity position.

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